Birds in remnant woodland vegetation in the central wheatbelt of New South Wales during the drought declared years 2005 to 2009

Murray V. Ellis[1] and Jennifer E. Taylor[2]

[1] Biodiversity Conservation Science Section, Office of Environment and Heritage, PO Box 1967, Hurstville BC NSW 1481,

[2] School of Arts and Sciences, Australian Catholic University, PO Box 968, North Sydney NSW 2059.

ABSTRACT

The woodlands of southern Australia have been extensively cleared for agriculture. The loss and fragmentation of the native vegetation has been followed by dramatic declines in woodland-dependant species. Here we present data from the Central Western Plains of New South Wales on the occurrence of birds in woodlands that have been highly fragmented and structurally altered over the last 150 years. The species composition of the region is still very similar to that recorded 3 decades earlier but many small insectivorous and nectivorous woodland birds are rare and restricted, while the woodland patches and remnant tree groves in the landscape are now dominated by the Galah, Noisy Miner, Australian Magpie, Crested Pigeon, Apostlebird, Magpie-lark, Grey-crowned Babbler, Australian Raven, Eastern Rosella and Pied Butcherbird.

Key words: declining birds, fragmented woodland, avian species composition, avian distributions, agricultural landscapes

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Introduction

Woodlands once covered a million square kilometres of Australia and dominated what are now the wheatbelts of south-eastern and south-western Australia (Yates and Hobbs 1997). Extensive grazing and clearing for cereal cropping has greatly reduced and modified these woodlands (Yates and Hobbs 1997; Cox *et al.* 2001; Lunt *et al.* 2006; Bedward *et al.* 2007), with much of what remains restricted to rocky ridges, very low fertility soils or in linear remnants along roads, fencelines and water courses (Appendix 1, photos 1 to 4). Alteration of ecosystem processes (*e.g.*, hydrology and soil formation) has often had undesirable consequences such as salinisation and extensive erosion (Hobbs 1993), resulting in dramatic changes in flora and fauna population sizes and distributions. Many bird species and communities have declined and are now restricted to native vegetation remnants, with the extent and causes reviewed recently by Ford (2011).

Clearing and fragmentation of the New South Wales (NSW) wheatbelt has been an ongoing process with most of the central west affected over the last century (Sivertsen 1993; Metcalfe *et al.* 2003; Bedward *et al.* 2007). During this time there have been declines of many types of woodlands and woodland bird species, resulting in their listing under the NSW *Threatened Species Conservation Act 1995* (e.g. Fuzzy Box Woodland on Alluvial Soils of the South Western Slopes, Darling Riverine Plains and Brigalow Belt South Bioregions listed as an endangered ecological community, and Diamond Firetail (Appendix 1, photo 10) and Hooded Robin listed as vulnerable species). About 50 bird species from central-western New South Wales (NSW) have been listed as threatened nationally or under various State legislations. Similar situations are reported for woodland reptiles (e.g., Browne *et al.* 2007) and arboreal mammals (e.g., van der Ree 2002). At the time of writing, sixty species and communities were listed for the Bogan-Macquarie subregion of the Central West Catchment Management Authority Region, the focal area of this study (http://www.threatenedspecies.environment.nsw.gov.au/tsprofile/cma_subregion_list.aspx?id=843). Further decline in fauna and flora populations of this area is likely as even when clearing ceases because extinctions are known to continue for subsequent decades (Ford *et al.* 2009; Szabo *et al.* 2011), due to the “extinction debt” (Tilman *et al.* 1994).

This area straddles the junction between areas dominated by Bassian species in the east and Eyerian species in the west (Fleming and Ellis 2002) so many bird species of the NSW wheatbelt are likely to have elevated risk of local extinction associated with being at the margins of their range (Doherty *et al.* 2003). Arid-adapted species can be reaching their eastern limits while mesic-adapted species can approach their western limits in this region and the additional strain imposed by landscape alteration on species already approaching their ecological limits may drive fluctuating local populations to eventual extinction causing species to contract towards the core of their distribution.

Conserving a species in these highly fragmented systems requires a plethora of information, with the most fundamental piece being whether the species is extant in a region. Additionally, good baseline data on population dynamics of species at their distribution limits is crucial for monitoring, understanding and managing the impacts of climate change. Beyond this, essential to conservation management is an understanding of how species respond to different remnant vegetation types, modified by altered soil nutrient levels and hydrological patterns (McGinness *et al.* 2010; Watson 2011), and scattered across a range of topographical positions and land-uses (Bennett and Watson 2011).

The overall aim of this study was to determine the occupancy by birds of woodland remnants that have been highly fragmented and structurally altered in an agricultural landscape. This paper reports the preliminary stages of this work, detailing the survey methods used and the bird species composition of the region's woodland against a background of historic data. Specifically we aimed to: (i) provide baseline information on status of bird species which can be used to make future comparisons in relation to vegetation or climatic change; (ii) examine gross changes over time by comparing our data with historical Royal Australasian Ornithologist Union (RAOU, now Birds Australia) data collected three decades earlier.

Methods

Study area

Our study area was centred on 148° 00' E, 32° 30' S and straddled four 1:100,000 mapsheets: Dandaloo (8433); Narromine (8533); Peak Hill (8532); and Tullamore (8432). It is in the area mapped for native vegetation by Metcalfe *et al.* (2003), and lies west of the 300m altitude contour along the Hervey Ranges and adjacent uplands. It covers parts of the plains and riparian zones of the Macquarie and Bogan Rivers within a 10,000 km^2 section of the wheat-sheep belt of central-western NSW (Fig. 1).

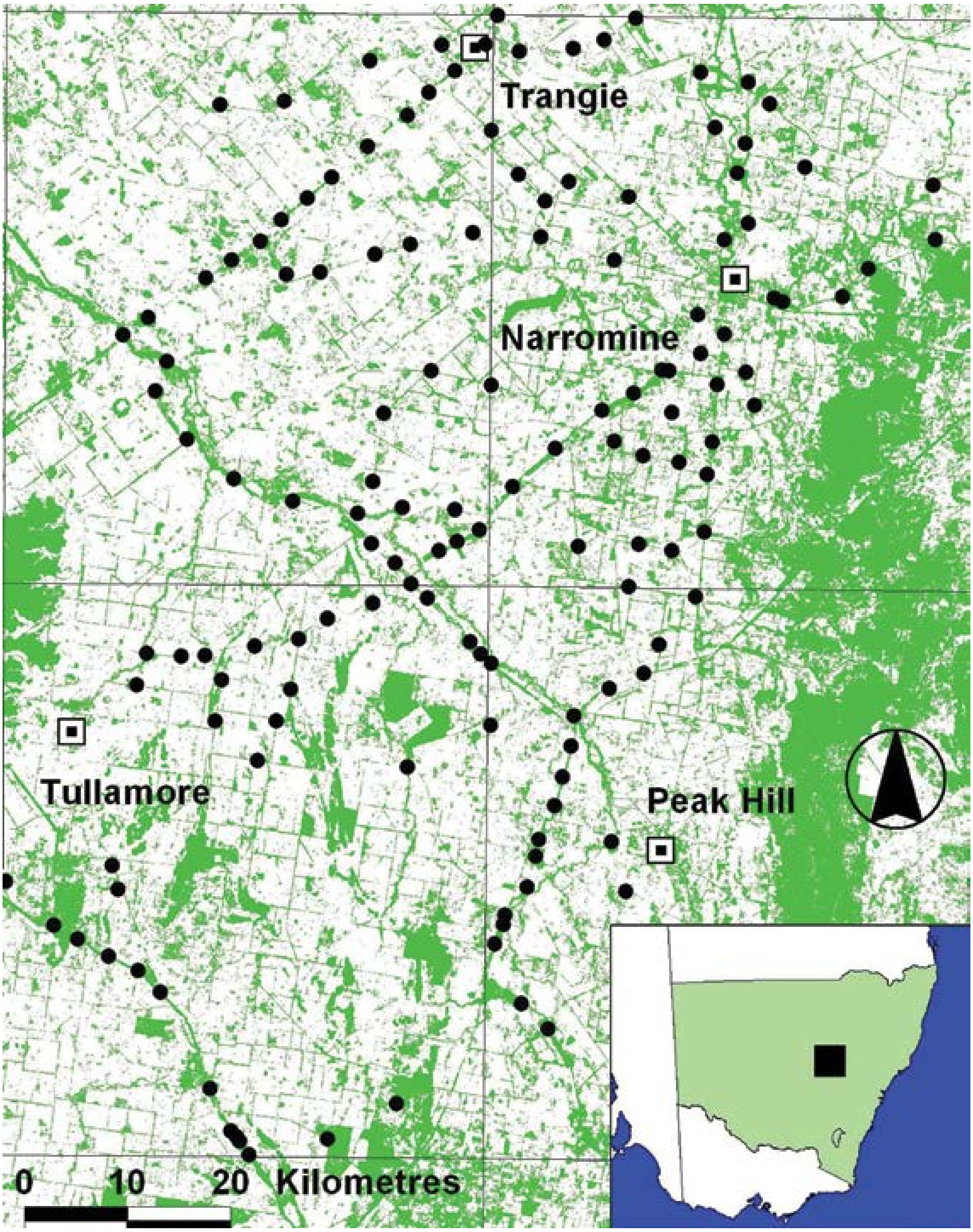

Figure 1. The distribution of survey sites in the study area. Remnant woody vegetation is shown as green on the main map.

The area of interest is predominantly alluvial plains and channels, originally dominated by *Eucalyptus, Callitris* and *Acacia* woodlands (Appendix 1, photos 5 to 8). Raised rocky areas dominated by *Eucalyptus* woodlands and forests are scattered within the study area (Metcalfe *et al.* 2003) (Fig. 2).

The woody vegetation of the region was substantially cleared and modified by rapid agricultural development in the late 1800s (Sivertsen 1993; Yates and Hobbs 1997; Sivertsen and Clarke 2000; Lunt *et al.* 2006; Bedward *et al.* 2007) (Fig. 1). The wheatbelt south of the study area was intensively cleared early in the 20th Century for cropping (Bedward *et al.* 2007). Concurrently the northern wheatbelt underwent a phase of thinning, using the technique of ringbarking that caused coppicing if a tree was not killed, followed later in the century by a phase of extensive clearing (Bedward *et al.* 2007). Over half of the remnant vegetation present in the early 1970s had been cleared in some northern sections of the NSW wheatbelt by 1990 (Sivertsen 1995). At the time of our study, the remaining woody native vegetation of the wheatbelt was primarily semi-arid *Eucalyptus-Callitris* woodland, with some areas of *Acacia* woodland and riparian River Red Gum (*Eucalyptus camaldulensis*) woodland

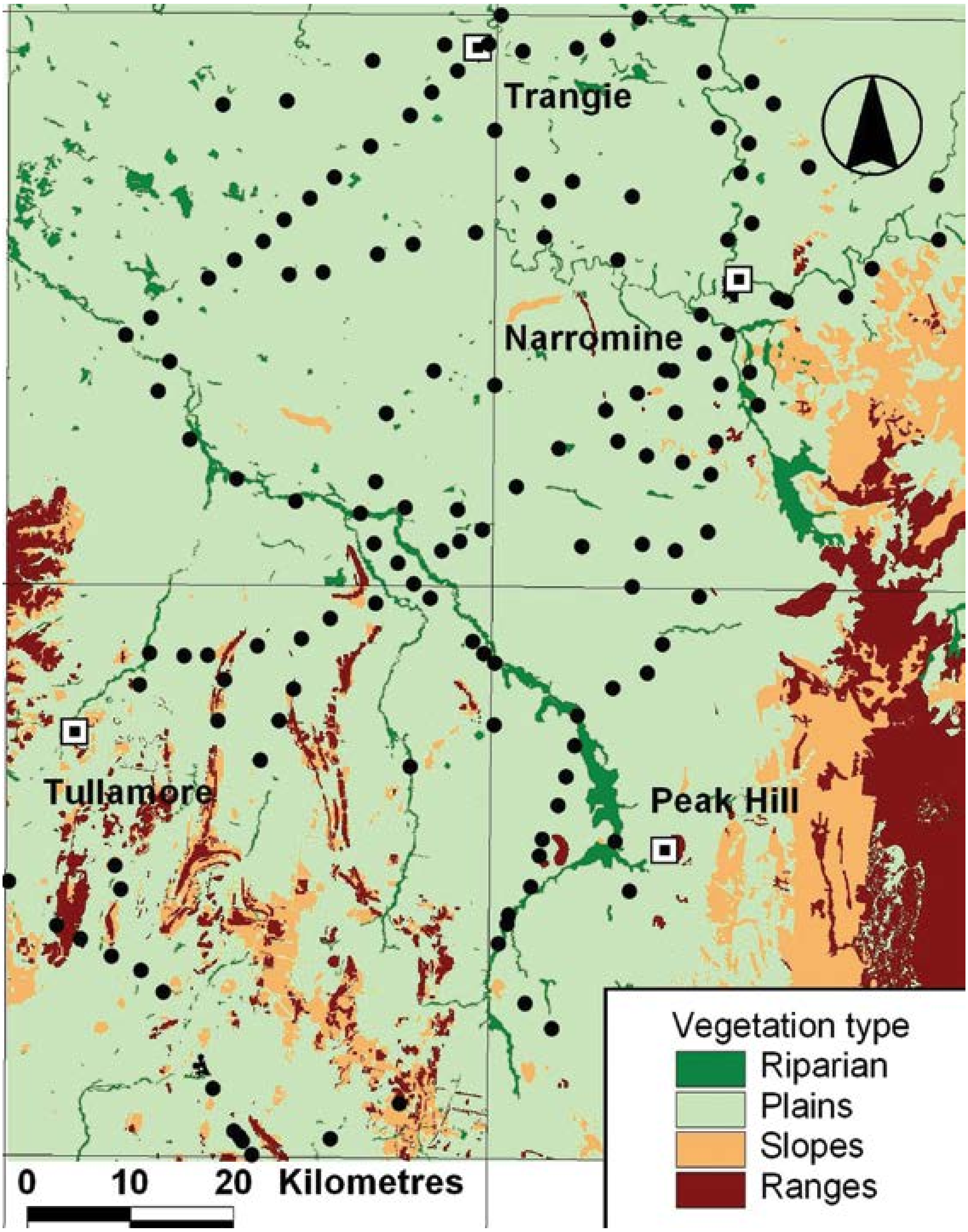

Figure 2. The distribution of landforms across the study region, each of which are characterised by their own suite of vegetation communities (see Metcalfe *et al.* 2003, Keith 2004).

(Metcalfe *et al.* 2003). Extensive areas of derived grassland were also present which may contain native grasses and forbs (Benson *et al.* 2006) (Appendix 1, photo 9).

The study area had been drought declared for nearly a decade in 2009, with 2006 at the beginning of our surveys being a particularly dry year (Fig. 3) after a series of years of around the 500mm average annual rainfall for the area. The region has high evaporation rates and the annual evaporation was in excess of 2000mm from 2001 to 2006 (Trangie Agriculture Research Station, Bureau of Meteorology www.bom.gov.au), greatly exceeding rainfall amount (Fig. 3). Records of evaporation for 2007 to 2009 were incomplete.

Bird sampling

One hectare (100m x 100m) sites were established at 142 locations (Fig. 1) over three survey periods. Sites were selected to cover the range of woodland densities in the remnants mapped by Metcalfe *et al.* (2003) and to cover the range of densities in the intervening agricultural matrix that were too sparse or narrow to be mapped by Metcalfe *et al.* (2003), mostly representing narrow linear remnants such as road verges. Sites had a minimum distance of 3 km to the nearest neighbouring site in the same vegetation type; seven sites were within 3 km of another site, all of a different vegetation type. Each one-hectare site was aligned with the Australian Mapping Grid so that it covered one grid cell in the raster version of the vegetation mapping of Metcalfe *et al.* (2003). Each site was in the centre of a 25-hectare plot (five by five grid of one-hectare cells) with a band of eight one-hectare immediate neighbouring cells, and an outer band of 16 cells.

Each site was surveyed between three and eight times per annum (median = 6) during the four spring/summer periods of the study, depending on when it was first established. Surveys occurred from 22 November 2005 to 8 April 2009. Each site was traversed for 10 minutes at each visit. Surveys were conducted during daylight without call playback. All birds detected during a survey were recorded with information on whether they were on the site (formal records in Table 2), in either of the surrounding bands of the plot or further from the site, including whether they were flying past, and the number of individuals detected. Weather (temperature, wind speed and any recent rainfall) and site condition details (ground cover, flowering and fruiting of mistletoe or eucalypts) were recorded for each visit for future analysis.

Data compilation

For each bird species we calculated the total number of times it was recorded during our surveys, how many records were within the one hectare sites and on how many sites each species was recorded. The records from the first Royal Australasian Ornithologists Union (RAOU) Bird Atlas (Blakers *et al.* 1984) were purchased and we extracted species records for their 10 minute cells that covered our study area and calculated the total number of records per species in the RAOU dataset. The collection of RAOU data varied among recorders in focus, duration and spatial extent and was aimed at recording broad distributions of species across large sampling units (approximately 18 km x 18 km) rather than site-specific information. Therefore, the

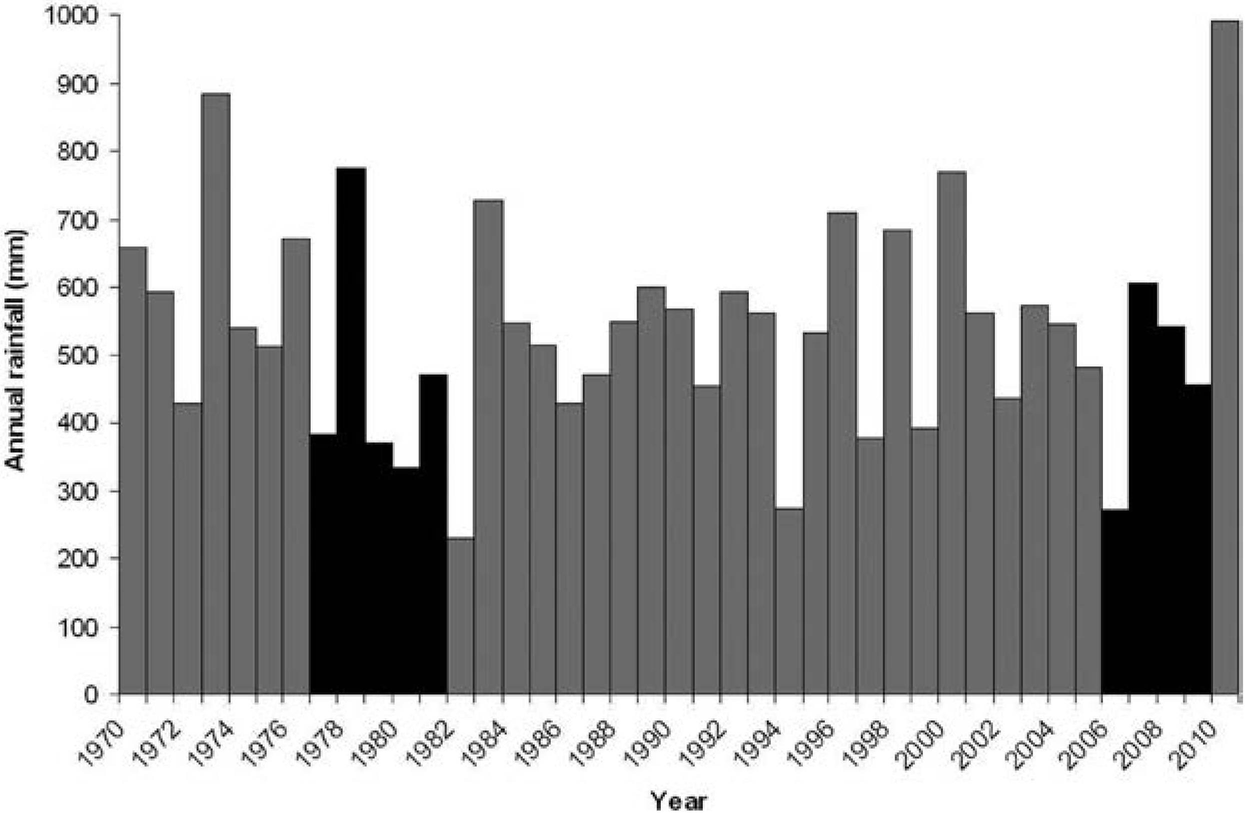

Figure 3. Annual rainfall at Narromine 1970 to 2010 with the two survey periods shown in black.

likelihood of the various species being recorded would not be expected to be equal between the RAOU and our approaches. Barrett *et al.* (2007) stated that the original RAOU methodology would favour reporting larger and more conspicuous species, especially ones that could be surveyed from moving cars.

Data filtering to remove the less frequently recorded species and statistical correction for survey effort can be attempted for large bird atlas datasets (Barrett *et al.* 2007), but the extent and size of the datasets for the study area did not warrant such analyses at this exploratory stage of the study. Consequently the datasets were treated as two simple snapshot samples to gain some insight into the detectability and abundance of each species.

Results

One hundred and thirty eight bird species were detected on sites during our study, 125 being considered landbird species and 13 being waterbirds. A further 42 species were detected outside the spatial or temporal boundaries of the timed 10 minute site counts, 17 of which were waterbirds that were seen at adjacent dams and watercourses or flying over. Fourteen of the land bird species detected are listed under the NSW *Threatened Species Conservation Act 1995.* The mean number of species detected per survey declined over time (Table 1) and varied between 0 and 36.

Both datasets contained a similar number of records (just over 24,000 records) so for each bird species the difference in number of records between the two datasets was calculated, revealing that only one fifth of the species were recorded more often in our study than the historic study. Consequently, we ranked the species according to the difference in the number of records and divided the ranked list into quintiles containing approximately equal numbers of species. The first four quintiles covered species recorded more often in the RAOU surveys or near equally in the two surveys; quintiles 3 and 4 are only slightly less recorded in our study compared to the RAOU study (Fig. 4). The fifth quintile is species recorded slightly to much more often in our study (Fig. 4).

Species more recorded in our surveys

The ten most-recorded (an indicator of abundance and detectability) species in our surveys were, in descending order, Galah, Noisy Miner, Australian Magpie, Crested Pigeon, Apostlebird, Magpie-lark, Grey-crowned Babbler, Australian Raven, Eastern Rosella and Pied Butcherbird. Species recorded at the greatest number of sites (an indicator of the extent of occupancy of the remnant woody vegetation) were, in descending order, Noisy Miner at 90% of sites, followed by Australian Magpie, Galah, Crested Pigeon, Eastern Rosella, Apostlebird, Red-rumped Parrot, Blue Bonnet, Grey-crowned Babbler and Magpie-lark. Of these species, all were within the top 20 most recorded in RAOU study with the exception of Grey-crowned Babbler (27th RAOU) and Blue Bonnet (22nd RAOU). All were seen more often in our surveys (quintile 5, Table 2). A full breakdown of the records is given in Table 2.

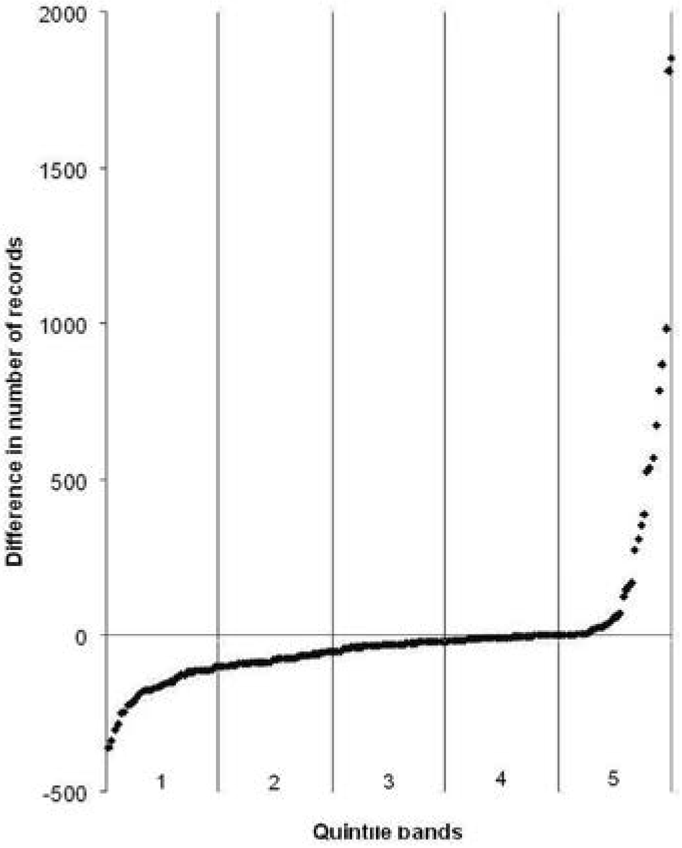

Figure 4. The pattern of the difference in the number of records per species in the two dataset (Difference = our dataset - RAOU dataset) when arranged in ascending order.

Eleven species seen in our surveys were not recorded in RAOU surveys (Table 2). All but two of these species (Little Corella and White-browed Treecreeper) had five or less records and all were recorded at only a few locations. Notable among the species for which there were few RAOU records was the Painted Honeyeater, for which only 17 records were collected during the RAOU surveys whereas it was recorded 78 times during our study at seven different locations. Species in the top quintile (quintile 5 in Table 2, more recorded in our

Table 1. The mean number of species detected on site per 10 minute survey for the four survey seasons.

year	2005/2006	2006/2007	2007/2008	2008/2009
mean no. species per survey	8.79	7.78	7.18	6.96
SD	4.84	4.42	3.11	2.97
Number of surveys	337	1032	853	699

Table 2. Birds recorded in the study area showing total number of records, number of records within the boundaries of the sites during formal 10 minute counts, number of sites on which each species was recorded, number of records in the RAOU dataset and the quintile ranking of the difference in the number of records ranging from 1 (far less recorded in our surveys) to 4 (slightly less recorded in our surveys,) and 5 (more recorded in our surveys). Records are arranged by quintile and then taxonomically. Nomenclature follows the Census of Australian Vertebrates. * = threatened species in NSW; † = species on edge of distributional range in our study area at the time of the RAOU surveys (Blakers et al. 1989).

Common Name	Scientific Name	All records	Formal records	Sites	RAOU records	Quintile
Little Pied Cormorant	*Phalacrocorax melanoleucos*	4	1	1	163	1
Australasian Grebe	*Tachybaptus novaehollandiae*	11	4	1	148	1
Grey Teal	*Anas gracilis*	26	5	2	196	1
Pacific Black Duck	*Anas superciliosa*	76	23	13	263	1
Australian Wood Duck	*Chenonetta jubata*	137	39	20	422	1
Black Swan	*Cygnus atratus*	2	0	0	114	1
White-necked Heron	*Ardea pacifica*	20	1	1	244	1
White-faced Heron	*Egretta novaehollandiae*	47	11	9	382	1
Yellow-billed Spoonbill	*Platalea flavipes*	21	1	1	188	1
Australian White Ibis	*Threskiornis molucca*	16	3	2	125	1
Straw-necked Ibis	*Threskiornis spinicollis*	15	1	1	232	1
Masked Lapwing	*Vanellus miles*	13	0	0	257	1
Black-shouldered Kite	*Elanus axillaris*	17	4	4	217	1
Brown Falcon	*Falco berigora*	23	6	5	199	1
Nankeen Kestrel	*Falco cenchroides*	62	15	13	420	1
Laughing Kookaburra	*Dacelo novaeguineae*	291	55	32	417	1
Rainbow Bee-eater	*Merops ornatus*	59	21	9	158	1
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	206	101	40	379	1
Yellow Thornbill	*Acanthiza nana*	64	46	23	219	1
Chestnut-rumped Thornbill	*Acanthiza uropygialis* †	37	25	15	137	1
Weebill	*Smicrornis brevirostris*	111	69	26	288	1
Jacky Winter	*Microeca fascinans*	60	31	12	187	1
Red-capped Robin	*Petroica goodenovii*	78	48	18	190	1
Grey Shrike-thrush	*Colluricincla harmonica*	116	38	20	269	1
Restless Flycatcher	*Myiagra inquieta*	34	13	5	210	1
Grey Fantail	*Rhipidura fuliginosa*	27	17	10	141	1
Willie Wagtail	*Rhipidura leucophrys*	461	189	51	576	1
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	270	85	53	417	1
Black-faced Woodswallow	*Artamus cinereus*	3	1	1	119	1
White-browed Woodswallow	*Artamus superciliosus*	25	14	9	155	1
Fairy Martin	*Hirundo ariel*	37	12	8	151	1
Welcome Swallow	*Hirundo neoxena*	28	10	8	331	1
Tree Martin	*Hirundo nigricans*	12	4	3	129	1
Australian Pipit	*Anthus novaeseelandiae*	5	2	1	220	1
House Sparrow	*Passer domesticus*	1	0	0	248	1
Double-barred Finch	*Taeniopygia bichenovii*	6	3	2	153	1
Common Starling	*Sturnus vulgaris*	410	156	43	521	1
Australian Pelican	*Pelecanus conspicillatus*	4	0	0	76	2
Great Cormorant	*Phalacrocorax carbo*	3	0	0	101	2
Little Black Cormorant	*Phalacrocorax sulcirostris*	3	1	1	79	2
Hardhead	*Aythya australis*	2	0	0	90	2
Plumed Whistling-Duck	*Dendrocygna eytoni*	2	1	1	55	2
Eurasian Coot	*Fulica atra*	1	0	0	79	2

Common Name	Scientific Name	All records	Formal records	Sites	RAOU records	Quintile
Dusky Moorhen	*Gallinula tenebrosa*	1	0	0	72	2
Great Egret	*Ardea alba*	4	1	1	62	2
Black-fronted Dotterel	*Elseyornis melanops*	1	0	0	100	2
Banded Lapwing	*Vanellus tricolor*	9	1	1	102	2
Black-winged Stilt	*Himantopus himantopus*	4	0	0	66	2
Whistling Kite	*Haliastur sphenurus*	17	2	2	70	2
Little Eagle	*Hieraaetus morphnoides* *	8	1	1	79	2
Rock Dove	*Columba livia*	1	0	0	93	2
Brown Treecreeper	*Climacteris picumnus* *	174	72	14	260	2
White-throated Treecreeper	*Cormobates leucophaeus* †	1	0	0	71	2
Superb Fairy-wren	*Malurus cyaneus* †	44	21	6	135	2
Inland Thornbill	*Acanthiza apicalis* †	7	3	3	92	2
Speckled Warbler	*Chthonicola sagittata* *	6	4	3	70	2
White-eared Honeyeater	*Lichenostomus leucotis*	2	1	1	100	2
Yellow-throated Miner	*Manorina flavigula* †	207	140	48	280	2
Brown-headed Honeyeater	*Melithreptus brevirostris*	3	2	2	90	2
Little Friarbird	*Philemon citreogularis*	126	48	20	182	2
Noisy Friarbird	*Philemon corniculatus*	10	4	3	98	2
Striped Honeyeater	*Plectorhyncha lanceolata*	117	36	23	180	2
White-browed Babbler	*Pomatostomus superciliosus*	3	1	1	93	2
Eastern Yellow Robin	*Eopsaltria australis*	71	36	10	168	2
Hooded Robin	*Melanodryas cucullata* *	8	5	2	80	2
Golden Whistler	*Pachycephala pectoralis*	0	0	0	56	2
Ground Cuckoo-shrike	*Coracina maxima*	3	0	0	64	2
White-winged Triller	*Lalage sueurii*	29	16	15	115	2
Dusky Woodswallow	*Artamus cyanopterus*	7	5	2	101	2
Pied Currawong	*Strepera graculina* †	25	5	3	89	2
Little Raven	*Corvus mellori*	35	10	8	99	2
Diamond Firetail	*Stagonopleura guttata* *	4	2	2	91	2
Zebra Finch	*Taeniopygia guttata*	14	9	4	104	2
Silvereye	*Zosterops lateralis*	0	0	0	71	2
Emu	*Dromaius novaehollandiae*	7	1	1	32	3
Stubble Quail	*Coturnix pectoralis*	7	2	1	36	3
Darter	*Anhinga melanogaster*	5	1	1	36	3
Glossy Ibis	*Plegadis falcinellus*	2	0	0	31	3
Brown Goshawk	*Accipiter fasciatus*	6	3	3	34	3
Spotted Harrier	*Circus assimilis* *	14	2	2	41	3
Australian Hobby	*Falco longipennis*	19	11	9	44	3
Peaceful Dove	*Geopelia striata*	212	33	12	240	3
Budgerigar	*Melopsittacus undulatus* †	9	2	2	31	3
Fan-tailed Cuckoo	*Cacomantis flabelliformis*	5	0	0	38	3
Horsfield's Bronze-Cuckoo	*Chrysococcyx basalis*	3	0	0	29	3
Southern Boobook	*Ninox novaeseelandiae*	3	0	0	25	3
Tawny Frogmouth	*Podargus strigoides*	1	0	0	31	3
Dollarbird	*Eurystomus orientalis*	45	13	10	88	3
Red-backed Kingfisher	*Todiramphus pyrrhopygia*	2	0	0	37	3
Varied Sittella	*Daphoenositta chrysoptera*	17	9	6	37	3
Variegated Fairy-wren	*Malurus lamberti*	7	5	4	27	3

Common Name	Scientific Name	All records	Formal records	Sites	RAOU records	Quintile
Southern Whiteface	*Aphelocephala leucopsis*	5	4	3	40	3
Spotted Pardalote	*Pardalotus punctatus*	4	3	2	43	3
Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	154	87	24	178	3
Red Wattlebird	*Anthochaera carunculata †*	2	1	1	35	3
Yellow-faced Honeyeater	*Lichenostomus chrysops †*	0	0	0	43	3
Fuscous Honeyeater	*Lichenostomus fuscus †*	1	1	1	42	3
White-plumed Honeyeater	*Lichenostomus penicillatus*	372	228	36	421	3
Singing Honeyeater	*Lichenostomus virescens †*	22	13	6	41	3
White-fronted Chat	*Epthianura albifrons †*	0	0	0	19	3
Crested Shrike-tit	*Falcunculus frontatus*	1	1	1	53	3
Crested Bellbird	*Oreoica gutturalis †*	2	0	0	21	3
Rufous Whistler	*Pachycephala rufiventris*	235	85	26	254	3
Olive-backed Oriole	*Oriolus sagittatus*	1	0	0	52	3
White-bellied Cuckooshrike	*Coracina papuensis*	0	0	0	31	3
White-breasted Woodswallow	*Artamus leucorhynchus*	9	3	2	43	3
Masked Woodswallow	*Artamus personatus*	2	0	0	41	3
Mistletoebird	*Dicaeum hirundinaceum*	122	76	30	161	3
White-backed Swallow	*Cheramoeca leucosternus*	2	0	0	21	3
Rufous Songlark	*Cinclorhamphus mathewsi*	144	48	26	179	3
Golden-headed Cisticola	*Cisticola exilis †*	2	0	0	24	3
Plum-headed Finch	*Neochmia modesta*	0	0	0	37	3
Brown Quail	*Coturnix ypsilophora †*	1	1	1	2	4
Painted Button-quail	*Turnix varia*	1	1	1	2	4
Little Button-quail	*Turnix velox*	1	1	1	5	4
Pied Cormorant	*Phalacrocorax varius*	7	0	0	19	4
Chestnut Teal	*Anas castanea*	1	0	0	18	4
Black-tailed Native-hen	*Gallinula ventralis †*	1	0	0	17	4
Intermediate Egret	*Ardea intermedia*	1	0	0	14	4
Nankeen Night Heron	*Nycticorax caledonicus*	6	1	1	16	4
Royal Spoonbill	*Platalea regia*	1	0	0	13	4
Wedge-tailed Eagle	*Aquila audax*	37	5	5	55	4
Swamp Harrier	*Circus approximans*	3	1	1	18	4
Square-tailed Kite	*Lophoictinia isura **	1	0	0	0	4
Black Kite	*Milvus migrans*	19	6	4	18	4
Grey Falcon	*Falco hypoleucos †*	1	0	0	1	4
Peregrine Falcon	*Falco peregrinus*	2	1	1	10	4
Bar-shouldered Dove	*Geopelia humeralis*	3	1	1	12	4
Major Mitchell's Cockatoo	*Cacatua leadbeateri * †*	7	2	2	12	4
Red-winged Parrot	*Aprosmictus erythropterus †*	1	0	0	2	4
Turquoise Parrot	*Neophema pulchella †*	2	0	0	11	4
Mulga Parrot	*Psephotus varius †*	2	0	0	5	4
Shining Bronze-Cuckoo	*Chrysococcyx lucidus*	1	1	1	3	4
Barking Owl	*Ninox connivens **	2	1	1	1	4
Australian Owlet-nightjar	*Aegotheles cristatus*	1	0	0	8	4
Spotted Nightjar	*Eurostopodus argus †*	1	1	1	6	4
Fork-tailed Swift	*Apus pacificus*	1	1	1	10	4
White-throated Needletail	*Hirundapus caudacutus*	3	0	0	14	4
Sacred Kingfisher	*Todiramphus sanctus*	138	42	15	146	4

Common Name	Scientific Name	All records	Formal records	Sites	RAOU records	Quintile
White-winged Fairy-wren	*Malurus leucopterus †*	7	2	1	24	4
Splendid Fairy-wren	*Malurus splendens †*	3	1	1	2	4
Brown Honeyeater	*Lichmera indistincta †*	1	0	0	0	4
Black-chinned Honeyeater	*Melithreptus gularis* *	2	2	2	20	4
White-naped Honeyeater	*Melithreptus lunatus*	2	1	1	7	4
Leaden Flycatcher	*Myiagra rubecula †*	2	1	1	8	4
Spangled Drongo	*Dicrurus bracteatus †*	1	1	1	0	4
Little Woodswallow	*Artamus minor †*	1	1	1	0	4
Skylark	*Alauda arvensis †*	1	1	1	2	4
Common Blackbird	*Turdus merula †*	2	0	0	2	4
Magpie Goose	*Anseranas semipalmata* * †	3	0	0	0	5
Diamond Dove	*Geopelia cuneata*	12	5	4	5	5
Crested Pigeon	*Ocyphaps lophotes*	1332	712	126	546	5
Common Bronzewing	*Phaps chalcoptera*	127	57	33	104	5
Sulphur-crested Cockatoo	*Cacatua galerita*	193	20	13	158	5
Galah	*Cacatua roseicapilla*	2536	945	128	685	5
Little Corella	*Cacatua sanguinea †*	57	4	4	0	5
Glossy Black-Cockatoo	*Calyptorhynchus lathami* * †	5	1	1	0	5
Cockatiel	*Nymphicus hollandicus*	689	183	78	415	5
Australian King-Parrot	*Alisterus scapularis †*	2	0	0	0	5
Mallee Ringneck	*Barnardius zonarius †*	198	119	54	169	5
Blue Bonnet	*Northiella haematogaster*	706	387	92	317	5
Eastern Rosella	*Platycercus eximius*	920	402	125	350	5
Superb Parrot	*Polytelis swainsonii †*	206	67	44	39	5
Red-rumped Parrot	*Psephotus haematonotus*	688	306	99	529	5
Black-eared Cuckoo	*Chrysococcyx osculans*	5	1	1	1	5
White-browed Treecreeper	*Climacteris affinis †*	11	2	2	0	5
Striated Thornbill	*Acanthiza lineata †*	5	4	4	3	5
Brown Thornbill	*Acanthiza pusilla †*	36	25	14	7	5
Buff-rumped Thornbill	*Acanthiza reguloides*	75	39	21	30	5
Western Gerygone	*Gerygone fusca*	259	85	27	114	5
Striated Pardalote	*Pardalotus striatus*	372	167	67	299	5
Blue-faced Honeyeater	*Entomyzon cyanotis*	126	54	37	94	5
Painted Honeyeater	*Grantiella picta* *	78	20	7	17	5
Noisy Miner	*Manorina melanocephala*	2267	1371	134	455	5
Grey-crowned Babbler	*Pomatostomus temporalis* *	941	216	89	268	5
Magpie-lark	*Grallina cyanoleuca*	1192	214	80	668	5
Pied Butcherbird	*Cracticus nigrogularis*	808	183	80	496	5
Grey Butcherbird	*Cracticus torquatus*	603	158	72	247	5
Australian Magpie	*Gymnorhina tibicen*	1627	429	131	643	5
Little Crow	*Corvus bennetti †*	32	8	8	11	5
Australian Raven	*Corvus coronoides*	926	67	50	386	5
White-winged Chough	*Corcorax melanorhamphos*	536	146	64	411	5
Apostlebird	*Struthidea cinerea*	1242	501	107	375	5
Singing Bushlark	*Mirafra javanica*	2	2	1	0	5
Australian Reed-Warbler	*Acrocephalus australis*	2	0	0	0	5
Brown Songlark	*Cinclorhamphus cruralis*	63	15	11	58	5

surveys) were generally the larger woodland birds such as the Australian Magpie, Noisy Miner and Galah. An exception is the Magpie Goose, a large waterfowl.

Parrots (Psittaciformes) were more recorded in our study than the RAOU study (mostly in quintile 5, Table 2), with the exception of the Budgerigar, Major Mitchell's Cockatoo and Turquoise Parrot plus four species with five or fewer records in either study. Little Corellas had the most dramatic increase (57 versus 0). Notable among species recorded more frequently in our study were the Superb Parrot and the Grey-crowned Babbler, both listed as threatened species in NSW.

Species more recorded in RAOU surveys

Six species were found during the RAOU surveys in this area but were not recorded during our study: Golden Whistler (56 records); Plum-headed Finch (37); Silvereye (71); White-bellied Cuckoo-shrike (31); White-fronted Chat (19); and Yellow-faced Honeyeater (43). Species that were much more recorded in the RAOU surveys (quintiles 1 and 2 in Table 2) consisted of a mixture of waterbirds and woodland birds.

Waterbirds were generally more recorded in the RAOU study than in our study and accounted for 20 of the species in quintiles 1 and 2 (Table 2). There were five species of waterbirds within the 40 most-recorded bird species in RAOU study but only one in our study (Australian Wood Duck rank 32). The Magpie Goose was the only waterbird recorded in our surveys and not recorded in the RAOU surveys.

Of the 54 landbird species that were in quintiles 1 or 2, 30 species (55.6%) were small (<35g) passerines. In comparison, of the 44 species of landbirds seen more times in our study than the RAOU study (quintiles 5), only 7 species (15.9%) were small (<35 g) passerines (Table 2). There were fewer records in our surveys for the cuckoo-shrikes (Campephagidae), whistlers (Pachycephalidae), robins (Petroicidae) and many of the thornbills (Pardalotidae), all insectivorous, as well as for many granivorous finches (Estrildidae) and insectivorous/nectivorous honeyeaters (Meliphagidae).

Species at similar abundance in both surveys

Quintile 4 and the adjacent tails of quintiles 3 and 5 represent those species that had relatively similar records in our study area in the two surveys (Fig. 4). There were 52 species for which abundances in the two surveys were within 20 records (Table 2); part of quintile 3 (seven species), quintile 4 and part of quintile 5 (9 species). Most (47 of 52) were species at low abundance in both surveys, fewer than 25 records in either survey (Table 2). The remaining five species had a maximum of 41 to 254 records: Singing Honeyeater (RAOU, 41 versus our survey 22), Wedge-tailed Eagle (55 versus 37), Brown Songlark (58 versus 63), Sacred Kingfisher (146 versus 138) and Rufous Whistler (254 versus 235) (Table 2). Theses species spanned a wide taxonomic range but just under half (25) of these 52 species were near the edge of their distributional range in our study area at the time of the RAOU survey (Blakers *et al.* 1984).

Species at the edge of their distributional range

Forty one of the species recorded were near the edge of their distributional range in our study area at the time of the RAOU survey (Blakers *et al.* 1984). Two of these 41 species were not recorded in our surveys; Yellow-faced Honeyeater (19 RAOU records) and White-fronted Chat (43 RAOU records). Eight of the 41 species were not recorded in RAOU surveys; seven with fewer than 12 records in our surveys and one species with 57 records (Little Corella).

Species at the edge of their distributional range in our study area at the time of the RAOU survey (Blakers *et al.* 1984) are marked in Table 2. In general, these species had lower site occupancy (all but five species at fewer than 10 sites; Table 2) than species not at the edge of their range (ANOVA: $\log_{10}$-transformed, $F = 7.914$, $P = 0.005$). They were also recorded less frequently than species not at the edge of their range in our survey (ANOVA: $\log_{10}$-transformed, $F = 16.230$, $P < 0.001$) and RAOU surveys (ANOVA: $\log_{10}$-transformed, $F = 7.914$, $P = 0.005$). Twelve species at the edge of their range had one to three records each in our surveys and were not recorded during formal survey time on sites.

Discussion

Our results show that during the drought-declared years of 2005 – 2009 the avifauna of the remnant native vegetation in the agricultural landscape of the Central Western Plains of NSW was dominated by large, generalist species, such as Galah and Magpie. Many of the small woodland birds that once would have been widespread in the region were patchily distributed in our surveys. This is a common situation in areas of modified woodland in all States in south-eastern Australia, *e.g.* the Mount Lofty Ranges in South Australia (Szabo *et al.* 2011), the Northern Plains of Victoria (Bennett and Ford 1997; Mac Nally *et al.* 2009), the New England Tablelands of NSW (Barrett *et al.* 1994) and the Southeast Queensland Bioregion (Martin and MacIntyre 2007).

Most, but not all, species recorded by the earlier RAOU study were still found during our surveys. However, our results are indicative of changes in relative abundance of a range of woodland bird species in the intervening years. Some differences in number of records between the two studies may reflect differences in methods or foci of the studies rather than actual changes in abundance. Other differences in number of records are unlikely to result purely from differences in the foci of the two studies and could indicate species or groups of concern.

Effects of study method and focus

We sampled only plains woodland in our study whereas the RAOU data collection was not thus restricted. As a result, some groups of birds would be expected to differ in detection between the two sets of data. Waterbirds would be expected to feature less in our results than theirs as occurred. However, it should be remembered that there has been a long-term decline in waterbirds in eastern Australia (Nebel *et al.* 2008). Similarly, the House Sparrow, Common Blackbird and Rock Dove that are associated with human settlements were less recorded during our study as none of our sites were in settlements or around homesteads.

Our surveys were diurnal and were mostly undertaken during spring and summer. Therefore, our study does not provide a reliable measure of abundance and distribution for nocturnal bird species or for winter nomads or migrants. Nevertheless, our records provide evidence of occupancy in the study area at the time.

Differences in relative abundance

Our results suggest that a range of woodland bird species have declined in relative abundance in the period since the RAOU surveys. Less frequent recording of some species potentially results from a combination of factors such as interactions with other species, the prevailing drought at the time of our study or on-going habitat loss.

In the period between the RAOU surveys and our surveys only 5 years recorded over 600 mm of rainfall. RAOU surveys were also during a period of drought but included a very wet year, and were preceded by a wetter period. Prolonged drought is likely to result in a depression in food resources (e.g., rodent numbers, Dickman *et al.* 1999; nectar, Mac Nally *et al.* 2009) with flow-on effects to species reliant on these resources (Schwinning and Sala 2004). Reduced numbers of most honeyeaters (Meliphagidae) and woodswallows (Artamidae), which also can have a high nectar component in their diet, may reflect lower nectar availability (e.g., Mac Nally *et al.* 2009). However, not all honeyeaters were at reduced abundance indicating other factors were contributing to the lower relative abundance of some species. Blue-faced Honeyeaters and Noisy Miners (but not the Yellow-throated Miner) were more frequently recorded during our study. The Noisy Miner (Appendix 1, photo 11) is now considered by many authors to be dominating many remnant areas of vegetation and is suspected of displacing other species (e.g. Grey *et al.* 1997; Clarke and Oldland 2007).

Trends found by Barrett and Silcocks (2002) for the entire Darling Riverine Plains Bioregion comparing the 1998-2001 Atlas results to the earlier Atlas results were often similar to our observations in our subset of the region. Most of the landbird species in our quintile 5 (more recorded) were rated by Barrett and Silcocks (2002) as stable or increaser species, while many of our quintile 1 (many fewer records) species were rated by Barrett and Silcocks (2002) as stable or decreasers. However, six species with far fewer records in our surveys (Black-shouldered Kite, Grey Shrike-thrush, Grey Fantail, White-browed Woodswallow, Welcome Swallow and Fairy Martin) had increasing trends in Barrett and Silcocks (2002). Of these six species only Grey Shrike-thrush and Grey Fantail would be considered woodland dependant species in the wheatbelt because of their foraging methods and mobility (Bennett and Ford 1997). The others are mobile aerial hunters often found foraging over open countryside wherever food is available. For example, Black-shouldered Kite densities are reported to fluctuate in response to House Mouse populations changes, with peak rodent populations being expected within a year after a drought period has ended (Saunders and Giles 1977) so a paucity of records during a drought period is to be expected.

The Silvereye and Golden Whistler, both Bassian species, reach the edge of their distribution west of our study area. The fact that neither was recorded in our surveys may reflect the timing of our surveys, as both are seasonal migrants which breed east of our study area (Blakers *et al.* 1984). However, both species were more frequently recorded in the 2nd Atlas of Australian Birds than the 1st (Barrett and Silcocks 2002) and our result may be a consequence of the prevailing drought conditions limiting their movement onto the plains.

Species on the margins of their distributional range

Many species recorded in our study were at the margin of their distributional range in our study area at the time of the RAOU surveys (Blakers *et al.* 1989). It is not unusual for species at the margins of their range to fluctuate in abundance with season or changes in habitat conditions (Opdam & Wascher 2004) and this may explain apparent changes in abundance of some species between the two studies here. For example, the lack of records of the mesic-adapted Yellow-faced Honeyeater may point to a species that had retreated eastward during the drought, but the RAOU data were recorded in cells that extended slightly further into the foothills of the Hervey Ranges so the species may have already been marginal to our study area on the plains. Fluctuations of in numbers of these species may be of less concern than that of more sedentary species in areas not impacted by human-induced disturbances. However, locations where species are at the edge of their range have been highlighted as important monitoring points for understanding the impacts of climate change, particularly in landscapes of fragmented habitat (Opdam & Wascher 2004).

At least two species had shown range expansions since the first Atlas study. Little Corellas appeared to have colonised the district since the RAOU study, and are increasing across most of eastern NSW (Barrett *et al.* 2007). The other species was the Magpie Goose which was considered almost extinct in inland NSW at the time of the RAOU study. Historically found around eastern Australia including the Murray-Darling Basin, at the time of the RAOU surveys it was restricted to north and north-eastern Australia (Blakers *et al.* 1989).

Time lag effects

Some changes in species abundances in the last 25 years may be associated with time lag effects associated with effects of habitat loss from clearing or gain from revegetation (Vesk and Mac Nally 2006, Vesk *et al.* 2008). If this is the case, then declines in some species would be expected to continue into the future in our study area associated with habitat loss over past few decades in this region (Bedward *et al.* 2007). Further declines may also be predicted for our study area associated with the slow attrition of vegetation from road verge clearing during road works, clearing for the installation of fences, collection for fire wood and storm damage.

Although the small woodland bird species were generally still surviving in this region, many were rarely recorded, and only in few locations, during the period of this study (*e.g.*, Double-barred Finch). Such an arrangement makes the local populations susceptible to extinction via stochastic losses of the remaining sub-populations or habitat patches. The low recording rate of many species, the potential for time-lag effects and the widespread declines of many of these woodland species (e.g., Mac Nally *et al.* 2009) is cause for concern.

Future directions

Each species with sufficient data will be analysed to determine the characteristics of where in the landscape it survived during this period of drought, with follow up surveys to determine whether these species increase their geographic range during wetter periods or whether they are now confined to a limited subset of the region. For some species, previous studies have found that remnant patch isolation is a strong predictor of patch occupancy (e.g. Varied Sittella and Jacky Winter, Miller and Cale 2000). With the advent of fine-scale mapping of foliage cover from satellite imagery, the original patch mapping by Metcalfe *et al.* (2003) has been superseded by a continuous woody vegetation foliage cover map without predefined remnant boundaries, so more sophisticated methods to describe patch size and isolation will be need when exploring the impacts of these factors on species distributions in the wheatbelt. In addition, population trends within these study sites are likely to require monitoring for at least a decade if significant, but possibly subtle, changes are to be detected (Field *et al.* 2007).

Grey-crowned Babblers have declined, often to the point of local extinction, in the southern parts of their range, particularly in Victoria and the Australian Capital Territory (Garnett and Crowley 2000). The area of decline coincides with early extensive clearing and planting of crops dependant on winter rainfall as mapped by Bedward *et al.* (2007). The widespread population of Grey-crowned Babblers (Appendix 1, photo 12) found in this study and adjacent areas by Major *et al.* (2001) are just north of these areas and they live in areas with a different development history where the shift to broad-scale cropping occurred only in the latter half of the 20th Century (Bedward *et al.* 2007). This gives us the opportunity to investigate the landscape needs of this species while there are still enough families in the landscape to provide detailed baseline distributional data against which any future spread of the population declines from the south, or decline due to extinction debt, can be assessed.

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References

Barrett, G.W., Ford, H.A. and Recher, H.F. 1994. Conservation of woodland birds in a fragmented rural landscape. *Pacific Conservation Biology* **1**: 245-256.

Barrett, G. and Silcocks, A. 2002. *Comparison of the first and second Atlas of Australian Birds to determine the conservation status of woodland-dependent and other bird species in New South Wales over the last 20 years*. Birds Australia, Melbourne.

Barrett, G.W., Silcocks, A.F., Cunningham, R., Oliver, D.L., Weston, M.A., Baker, J. 2007. Comparison of atlas data to determine the conservation status of bird species in New South Wales, with an emphasis on woodland-dependent species. *Australian Zoologist* **34**: 37-77.

Bedward, M., Simpson, C.C., Ellis, M.V. and Metcalfe, L.M. 2007. Patterns and determinants of historical woodland clearing in central-western New South Wales, Australia. *Geographical Research* **45**: 348-57.

Bennett, A.F., and Ford, L.A. 1997. Land use, habitat change and the distribution of birds in fragmented rural environments: a landscape perspective from the northern plains, Victoria, Australia. *Pacific Conservation Biology* **3**: 244–261.

Bennett, A.F. and Watson, D.M. 2011. Declining woodland birds - is our science making a difference? *Emu* **111**: i-vi.

Benson, J., Allen, C.B., Togher, C and Lemmon, J. 2006. New South Wales Vegetation Classification and Assessment: Part 1 Plant communities of the NSW Western Plains. *Cunninghamia* **9**: 383-451.

Blakers, M, Davies, S.J.J.F. and Reilly, P.N. 1984. *The Atlas of Australian birds*. Melbourne University Press, Melbourne.

Browne, G.W., Bennett, A.F. and Potts, J.M. 2008. Regional faunal decline – reptile occurrence in fragmented rural landscapes of south-eastern Australia. *Wildlife Research* **35**: 8-18.

Clarke, M.F. and Oldland, J.M. 2007. Penetration of remnant edges by noisy miners (*Manorina melanocephala*) and implications for habitat restoration. *Wildlife Research* **34**: 253–261.

Cox, S.J., Sivertsen, D.P. and Bedward, M. 2001. Clearing of native woody vegetation in the New South Wales northern wheatbelt: extent, rate of loss and implications for biodiversity conservation. *Cunninghamia* **7**: 101-155.

Dickman, C.R., Mahon, P.S., Masters, P. and Gibson, D.F. 1999. Long-term dynamics of rodent populations in arid Australia: the influence of rainfall. *Wildlife Research* 26: 389-403.

Doherty, P.F., Jr., Boulinier, T. and Nichols, J.D. 2003. Local extinction and turnover rates at the edge and interior of species' ranges. *Annales Zoologici Fennici* **40:** 145-153.

Field, S.A., O'Connor, P.J., Tyre, A.J. and Possingham, H. P. 2007. Making monitoring meaningful. *Austral Ecology* **32**: 485–491.

Fleming, M. and Ellis, M. 2002. Crossing the Bassian-Eyerian Divide: the bird communities of NSW. In *Proceeding of the Birds Australia Conference 2002* (Birds Australia, Melbourne).

Ford, H.A., Walters, J.R., Cooper, C.B., Debus, S.J.S. and Doerr, V.A.J. 2009. Extinction debt or habitat change? – Ongoing losses of woodland birds in north-eastern New South Wales, Australia. *Biological Conservation* **142**: 3182–3190.

Ford, H. A. 2011. The causes of decline of birds of eucalypt woodlands: advances in our knowledge over the last 10 years. *Emu* **111**: 1–9.

Garnett, S.T. and Crowley, G.M. 2000. *The action plan for Australian birds*. Environment Australia, Canberra.

Grey, M.J., Clarke, M.F. and Loyn, R.H. 1997. Initial changes in the avian communities of remnant eucalypt woodlands following a reduction in the abundance of noisy miners, *Manorina melanocephala*. *Wildlife Research* **24**: 631-648.

Hobbs, R.J. 1993. Effects of landscape fragmentation on ecosystem processes in the Western Australian wheatbelt. *Biological Conservation* **64**: 193-201.

Lunt, I.D., Jones, N.J., Spooner, P.G. and Petrow, M. 2006. Effects of European colonization on indigenous ecosystems: post-settlement changes in tree stand structures in *Eucalyptus-Callitris* woodlands in central New South Wales, Australia. *Journal of Biogeography* **33**: 1102-1115.

McGinness, H.M, Arthur, A.D. and Reid, J.R.W. 2010. Woodland bird declines in the Murray–Darling Basin: are there links with floodplain change? *Australian Rangelands Journal* **32**: 315-327.

Mac Nally, R., Bennett, A.F., Thomson, J.R., Radford, J.Q., Horrocks, G. and Vesk, P.A. 2009. Collapse of an avifauna: climate change appears to exacerbate habitat loss and degradation. *Diversity and Distributions* **15**: 720-730.

Mac Nally, R., Soderquist, T.R. and Tzaros, C. 2000. The conservation value of mesic gullies in dry forest landscapes: avian assemblages in the box-ironbark ecosystem of southern Australia. *Biological Conservation* **93**: 293-302.

Major, R.E., Christie, F.J. and Gowing, G. 2001. Influence of remnant and landscape attributes on Australian woodland bird communities. *Biological Conservation* **102**: 47-66.

Martin, T.G. and McIntyre, S. 2007. Impacts of livestock grazing and tree clearing on birds of woodland and riparian habitats. *Conservation Biology* **21**: 504–514.

Metcalfe, L., Sivertsen, D.P., Tindall, D. and Ryan, K.M. 2003. Natural vegetation of the New South Wales wheat-belt (Cobar-Nyngan-Gilgandra, Nymagee-Narromine-Dubbo 1:250 000 vegetation sheets). *Cunninghamia* **8**: 253-284.

Milller, J.R. and Cale, P. 2000. Behavioural mechanisms and habitat use by birds in a fragmented agricultural landscape. *Ecological Applications* **10**: 1732–1748.

Nebel, S., Porter, J. and Kingsford, R.T. 2008. Long-term trends of shorebird populations in eastern Australia and impacts of freshwater extraction. *Biological Conservation* **141**: 971-980.

Opdam, P. and Wascher, D. 2004. Climate change meets habitat fragmentation: linking landscape and biogeographical scale levels in research and conservation. *Biological Conservation* **117:** 285-297.

Saunders, G.R. and Giles, J.R. 1977. A relationship between plagues of the House Mouse, *Mus musculus* (Rodentia:Muridae) and prolonged periods of dry weather in south-eastern Australia. *Australian Wildlife Research* **4**: 241–247.

Schwinning, S. and Sala, O.E. 2004. Hierarchy of responses to resource pulses in arid and semi-arid ecosystems. *Oecologia* **141:** 211-220.

Sivertsen, D. P. 1993. Conservation of remnant vegetation in the box and ironbark lands of New South Wales. *Victorian Naturalist* **110**: 24-9.

Sivertsen, D. 1995. Habitat loss, its nature and effects (including case studies from New South Wales). In 'Conserving Biodiversity: Threats and Solutions'. (Eds R. A. Bradstock, T. D. Auld, D. A. Keith, R. T. Kingsford, D. Lunney and D. P. Sivertsen.) pp. 29–42. Surrey Beatty and Sons: Sydney.

Sivertsen, D. P. and Clarke, P. J. 2000. Temperate woodlands in New South Wales: a brief overview of distribution, composition and conservation. In: R.J. Hobbs and C. J. Yates (Eds.), *Temperate Eucalypt Woodlands in Australia*. Surrey Beatty & Sons: Sydney. pp. 6-16.

Szabo, J.K., Vesk, P.A., Baxter, P.W.J. and Possingham, H.P. 2011. Paying the extinction debt: woodland birds in the Mount Lofty Ranges, South Australia. *Emu* **111**: 59-70.

Tilman, D., May, R.M., Lehman, C.L., Nowak, M.A. 1994. Habitat destruction and the extinction debt. *Nature* **371**: 65.

van der Ree, R. 2002. The population ecology of the squirrel glider (*Petaurus norfolcensis*) within a network of remnant linear habitats. *Wildlife Research* **29**: 329–340.

Vesk, P.A. and Mac Nally R. 2006. The clock is ticking – Revegetation and habitat for birds and arboreal mammals in rural landscapes of southern Australia. *Agriculture, Ecosystems and Environment* **112**: 356-366.

Vesk, P.A., Nolan R., Thomson, J.R., Dorrough, J.W. and Mac Nally R. 2008. Time lags in provision of habitat resources through revegetation. *Biological Conservation* **141**: 174-186.

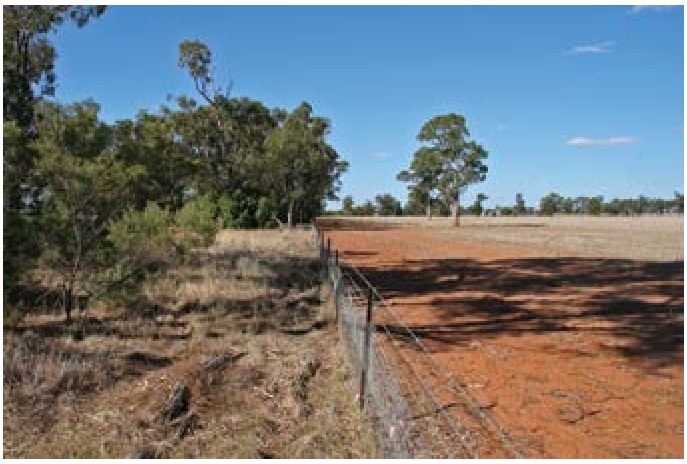
Watson, D.M. 2011. A productivity-based explanation for woodland bird declines: poorer soils yield less food. *Emu* **111**: 10-18.

Yates, C.J. and Hobbs, R.J. 1997. Temperate eucalypt woodlands: a review of their status, processes threatening their persistence and techniques for restoration. *Australian Journal of Botany* **45**: 949-973.

APPENDIX I

A narrow strip of Eucalyptus and Callitris between the side of a dirt road (foreground) and a cleared paddock (background). Photo, M. Ellis.

A wide roadside strip of Eucalyptus woodland. Photo, M. Ellis.



Distinct boundary effects where a roadside remnant abuts a paddock. A firebreak along the fenceline separates paddock trees and stubble from the remnant. Photo, M. Ellis.

Measuring tree dimensions and counting hollows in a linear remnant of River Red Gums on the Bogan River channel. Photo, M. Ellis.

APPENDIX I

A bird survey being conducted in an open Grey Box woodland site. Photo, M. Ellis.

A Yellowbox woodland with a few small Callitris as an understorey. Photo, M. Ellis.

A stand of Callitris with a surveyor in mid-photograph. Some areas of Callitris are much denser than this, limiting visibility. Photo, M. Ellis.

Monospecific stands of Myall occur on the grey clay soils of the plains. Photo, M. Ellis.

APPENDIX I

Although much of the cleared land is used for cropping, many areas of derived grassland exist with scattered patches of remnant woodland or isolated trees within them. Both introduced and native grasses and forbs occur in these areas. Photo, M. Ellis.

The Diamond Firetail, as well as other finches, were rarely found during the drought years of the surveys. Photo, M. Ellis.

The Noisy Miner is widespread in the area and was found at almost all of the sites. Photo, M. Ellis.

APPENDIX I

Grey-crowned Babblers were widespread in the study area where they probe through the leaf litter in search of invertebrates. Photo, M. Ellis.